TRANSPORTATION LEARNING NETWORK

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Welcome!

Assessment of Safe Work Indicators in Transportation Construction Using Personal Monitoring Systems

Presented by:

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Our partners:

Mountain-Plains Consortium · Montana Department of Transportation · North Dakota Transportation · SD Department of Transportation · Wyoming Transportation Department · NDSU · Upper Great Plains Transportation Institute, Transportation Learning Network

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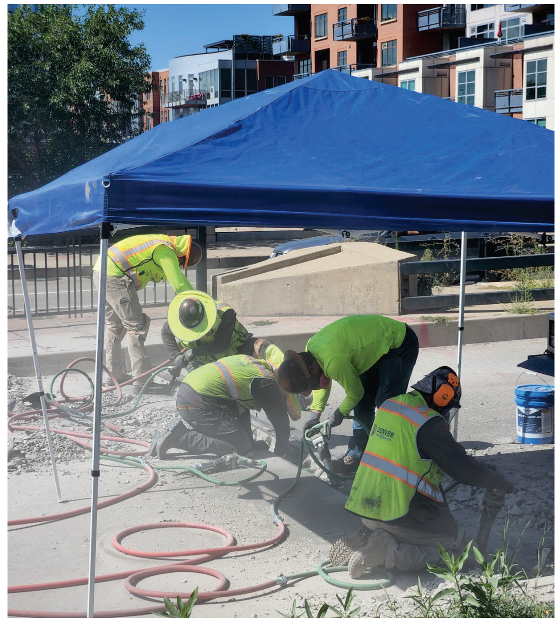
Introduction & Background

Transportation construction projects involve:

- Physically demanding work, including heavy lifting
- Long working hours
- Hazardous environments



Introduction & Background

20% to 40% of construction workers exceed physiological thresholds.

Physically demanding work, fatigue, accidents and injuries

Introduction & Background

- Physiological Status Monitoring (PSM) devices
- Heart rate is a reliable indicator of physical demand and workload
- Limited research exists on assessing physical demand in transportation construction

Research Objectives

- Apply a non-intrusive system to monitor and assess the physical demand of transportation construction workers.
- Analyze variations in physical demand across different transportation construction activities.
- Assess workers' heart rates against acceptable physiological thresholds.
- Analyze physiological factors affecting heart rate and model and forecast heart rate based on physical activity.
- Develop deep learning models to forecast the heart rate of construction workers.

Physiological Status Monitoring Device

The Zephyr Bioharness is a wireless chest-based wearable PSM device

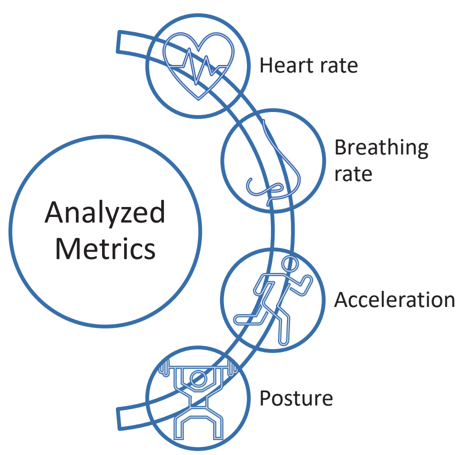
Adjustable strap with skin conductive electrodes to capture ECG signals

A three-axis accelerometer sensor

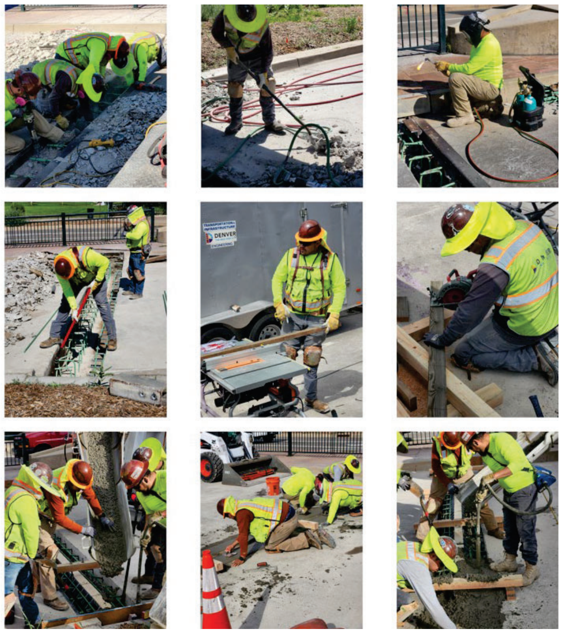
The device can record up to 36 hours of physiological data

Physiological Status Monitoring Device

- Real-Time Continuous Data Recording
- Impulse load
- HR confidence

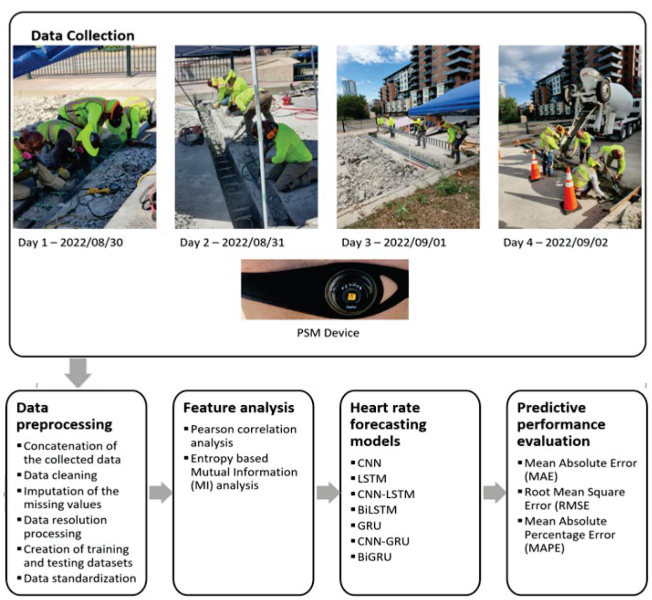


Data Collection and Experiment Protocol

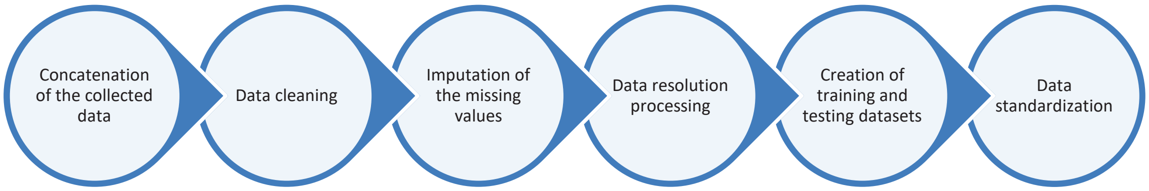


- Participants
- Study Duration
- Data Collection
- Data Privacy
- IRB Approval
- Voluntary Participation

Research Development Steps



Data Preprocessing



Physical Demand Analysis

$$\%HRR = \frac{HR - HR_{Rest}}{HR_{Max} - HR_{Rest}} \quad (1)$$

$$HR_{Max} = 208 - 0.7 \times Age \quad (2)$$

%HRR *Zones, thresholds, description, and respective suggestions Adapted from (Norton et al. 2010)*

%HRR Zones	%HRR Range	Description	Suggestions
Sedentary	0%-20%	Activities that have little movements and a low energy requirement (MET < 1.6)	An intensity that can be sustained over 60 minutes
Light	20%-40%	Activities that do not cause a noticeable change in breathing rate (1.6 < MET < 3)	An intensity that can be sustained over 60 minutes
Moderate	40%-60%	Activities that can be conducted whilst maintaining a conversation uninterrupted (3 < MET < 6)	An intensity that may last 30 to 60 minutes
Vigorous	60%-85%	Activities in which a conversation generally cannot be maintained uninterrupted (6 < MET < 9)	An intensity that may last up to 30 minutes
High	85%-100%	Activities that have a very high energy requirement (> 9 MET)	An intensity that generally cannot be maintained for longer than 10 minutes

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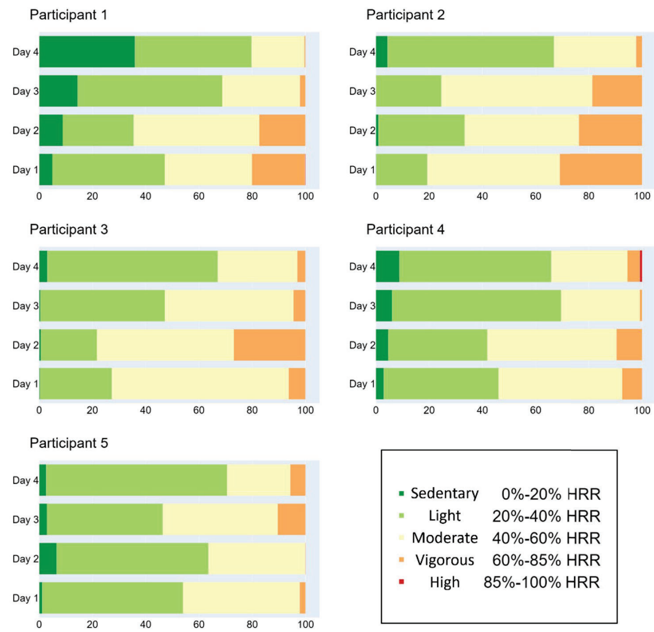
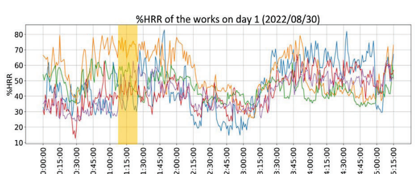
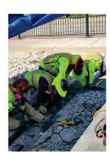
Physical Demand Analysis



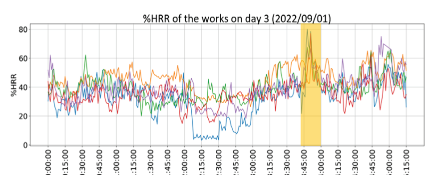
Sedentary	0%-20% HRR
Light	20%-40% HRR
Moderate	40%-60% HRR
Vigorous	60%-85% HRR
High	85%-100% HRR

Physical Demand Analysis

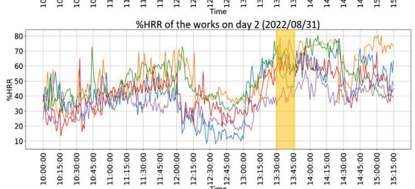


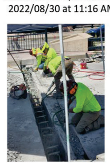


Jackhammer operation on 2022/08/30 at 11:16 AM

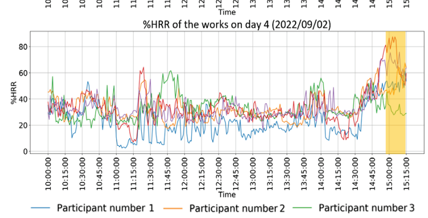


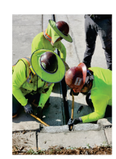
Expansion joint placement on 2022/09/01 at 1:51 PM





Jackhammer operation on 2022/08/31 at 1:42 PM





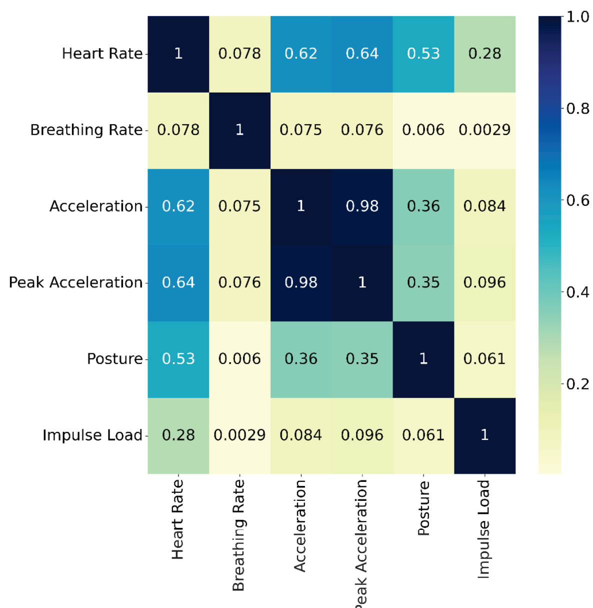
Installing the expansion joint gland on 2022/09/02 at 3:08 PM

Heart Rate Forecasting ML Methods

- CNN
- LSTM
- CNN-LSTM
- BiLSTM
- GRU
- CNN-GRU
- BiGRU

Results and Discussion

Correlation heatmap of the physiological metrics



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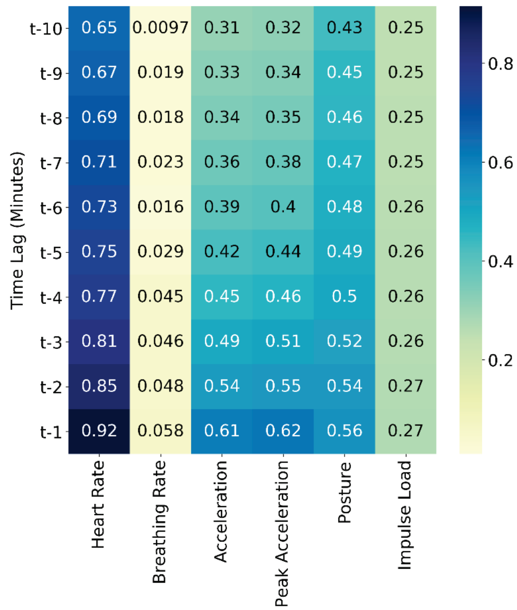
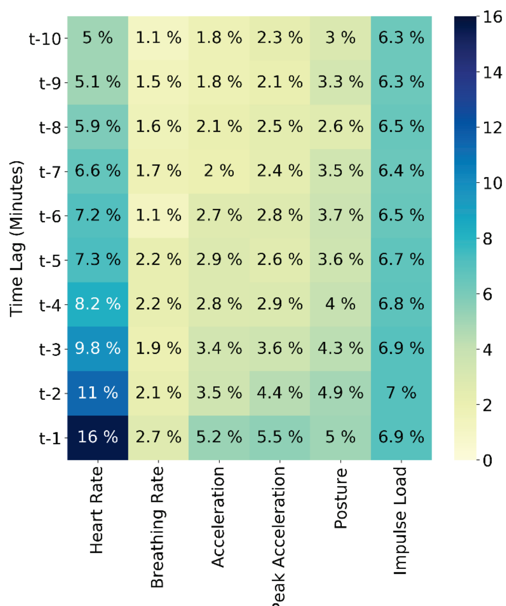
Results and Discussion

Dependencies between time-lagged variables and HR using Pearson correlation



Results and Discussion

Dependencies between time-lagged variables and HR using KNN-MI method



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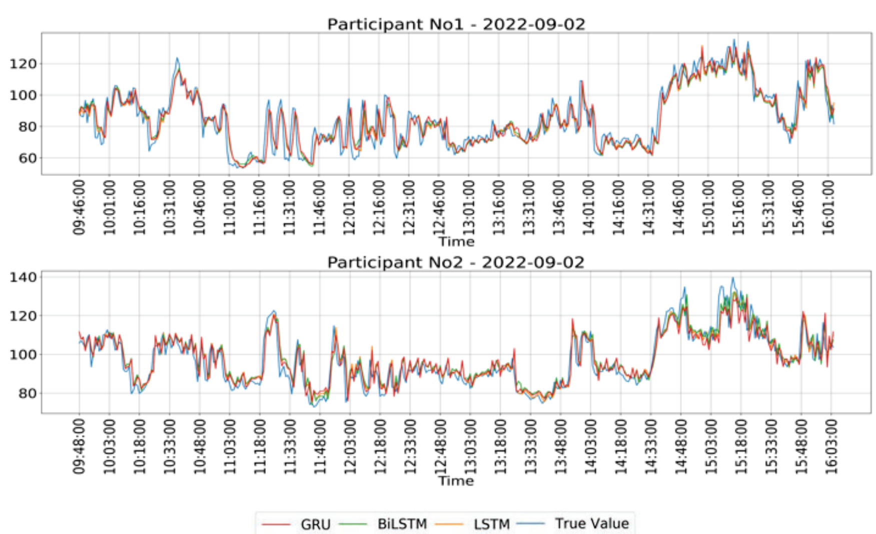
Results and Discussion

Performance evaluation of the developed deep learning models

Subject Number	Metric	LSTM	BiLSTM	GRU	BiGRU	CNNLSTM	CNNGRU	CNN
1	MAE	5.78	5.96	5.96	6.37	6.36	6.65	6.96
	RMSE	8.03	8.07	8.14	8.54	8.68	8.91	9.38
	MAPE	6.96%	7.24%	7.26%	7.83%	7.70%	8.02%	8.50%
2	MAE	4.31	4.47	4.43	4.49	4.75	5.27	8.71
	RMSE	5.90	5.95	5.94	5.79	6.05	6.68	12.39
	MAPE	4.45%	4.63%	4.54%	4.68%	4.98%	5.52%	9.39%
3	MAE	5.79	5.80	5.85	5.69	6.14	5.91	6.04
	RMSE	7.99	8.09	7.96	7.88	8.19	7.96	8.18
	MAPE	5.92%	5.93%	5.98%	5.79%	6.35%	6.05%	6.21%
4	MAE	5.75	5.81	5.75	6.06	6.18	6.39	6.19
	RMSE	7.70	7.70	7.80	9.30	8.29	8.83	8.54
	MAPE	5.96%	6.07%	5.92%	6.14%	6.36%	6.45%	6.30%
5	MAE	5.38	5.20	5.35	5.75	5.66	5.39	5.71
	RMSE	7.08	6.93	7.14	7.60	7.40	7.15	7.52
	MAPE	5.57%	5.37%	5.53%	5.92%	5.86%	5.50%	5.90%
Average	MAE	5.40	5.45	5.47	5.67	5.82	5.92	6.72
	RMSE	7.34	7.35	7.39	7.82	7.72	7.91	9.20
	MAPE	5.77%	5.85%	5.85%	6.07%	6.25%	6.31%	7.26%

Results and Discussion

One-minute Ahead Predictions of the Top Three Models: LSTM, BiLSTM, and GRU for Participants 1 and 2.



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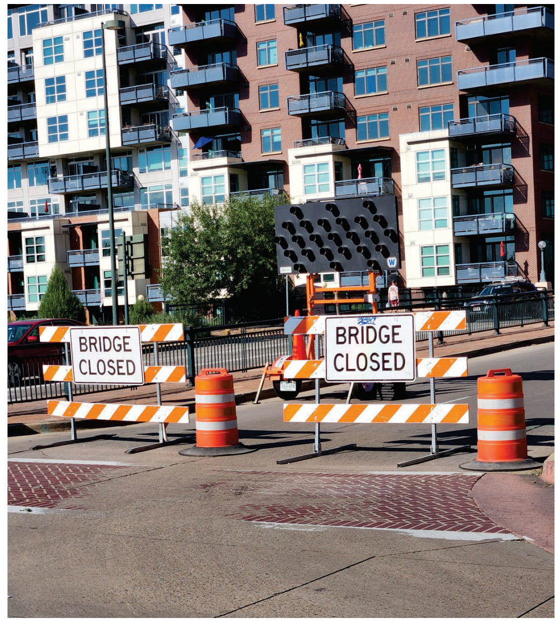
Summary and Conclusions

- Physical Demands across construction activities
- High %HRR Activities
- Influential Time-Lagged Variables
- LSTM Performance
- Real-Time Forecasting
- Work-Rest Scheduling
- Broader Applications



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Thank you for participating!

Please take a moment to complete the evaluation included in the reminder email.

We appreciate your feedback.

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